LOCATION
The lab and lectures take place in Duane G-214.

INSTRUCTORS
Dmitry Reznik: dmitry.reznik@colorado.edu
David Pappas: david.pappas@nist.gov

WEB SITE/CANVAS
The web site for the class has general information, the most up-to-date scheduling information, and most of the lab guides: http://www.colorado.edu/physics/phys4430
Also check frequently CANVAS course website. Important course announcements will be made on CANVAS course pages.

ON BEING AN EXPERIMENTALIST
How much time does an experimentalist spend doing physics? The answer depends deeply upon your understanding of how physics, an experimentally based field of knowledge, actually works. You might think the answer is, “Not much.”, and you'd be right if you think of ‘doing physics’ as making the discovery, or even simply conceiving of an experiment. In fact, an experimental physicist's time is largely spent ‘doing physics’ throughout the design and construction of experimental systems and components. If you don’t understand the physics of your experiment, then there is only a small chance that you’ll use it to successfully understand new physics. Often an experimentalist’s time is spent trying to understand why an experiment isn’t working, or at least is not working as expected. They need to figure out what modifications, both in apparatus and in understanding, they need to make. The demonstration of Bose-Einstein Condensation here at the University of Colorado generated a lot of excitement in the scientific community. That was an experiment five or six years in the making. It could be said that it was five or six years in the trying, before everything (intellectual understanding and experimental techniques) converged to a successful outcome.

So, what is experimental physics training all about? A good experimental physicist has a deep knowledge of physical principles and a broad range of skills in addition to an expertise in some particular field of physics. The standard intellectual equipment list includes familiarity with several engineering disciplines such as electronics, mechanical design, strength of materials, and vacuum technology and familiarity with instrumentation such as oscilloscopes, frequency counters, spectrum analyzers, voltmeters, and the like. What distinguishes a good experimental physicist from a highly skilled technician? A good experimentalist is a highly skilled technician, yet the physicist has a very different set of goals: the outcome is verification of a theory, or a demonstration of some new principle, or the like, and the skills are used is to get from here to there in the shortest path. During the test of the first atom bomb, Enrico Fermi was said to be seen dropping bits of paper; by observing
their horizontal motion relative to their vertical fall, Fermi was able to estimate the energy of the blast. Nothing fancy, no sophisticated instrumentation, just simple physical principles gave him the rough answer he was looking for. Furthermore, a physicist’s knowledge of physical principles allows them to be a generalist -- in this lab what you might learn about impedance matching in electronic circuits will enable you to generalize to impedance matching in mechanical systems to make a better machine, or in quantum physics to transfer wave functions.

The Advanced Laboratory course is designed to expose you to and equip you with some of the essential skills that an experimentalist should have. It is also designed to expose you to a variety of experimental physics topics, and to provide a sense of truly independent research.

**ORGANIZATION**

The two courses (PHYS4430 and PHYS5430) share facilities, instructors and meeting times. PHYS4430 is for undergraduates who have already taken PHYS3330, or an equivalent course in laboratory electronics. PHYS5430 is for graduate students, without prerequisites, or undergraduates who have already taken 3330 and 4430. Students should work in pairs (up to 2 people) throughout the term.

The various course requirements are summarized below.

**Summary of Laboratory Requirements – ALL Submissions to CANVAS Course Page**

<table>
<thead>
<tr>
<th>What</th>
<th>When</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture attendance</td>
<td>Tuesday and Thursday 9-9:50 am <strong>Attendance is mandatory</strong> for the entire semester.</td>
</tr>
<tr>
<td>Lab attendance</td>
<td>Tuesday 10 am – 12:50 pm <strong>Attendance is mandatory</strong> during this time for the entire semester.</td>
</tr>
<tr>
<td>Pre-lab for Lab 2 to 5.</td>
<td>Due at 9:00AM on Tuesday, the day you start the experiment.</td>
</tr>
<tr>
<td>Lecture Activities</td>
<td>See course schedule for various submission dates</td>
</tr>
<tr>
<td>Oral or written reports (Labs 1-5)</td>
<td>One of 5 labs should be submitted in a written report and 4 labs result should be in oral presentation. Presentation file (one for team) and written reports (individual) should be submitted at the same time as the lab notebook scan (below). Presentation will be during lecture period.</td>
</tr>
<tr>
<td>Lab notebook scans</td>
<td>Due at 11:59pm on Monday when you submit your lab presentations or written report. For Project weeks, 11:59 pm on Monday every week.</td>
</tr>
<tr>
<td>Project Proposal Draft</td>
<td>Draft due at 11:59 pm Mar 10 (Tue)</td>
</tr>
<tr>
<td>Project Proposal</td>
<td>Due at 11:59 pm Mar 19 (Thu.)</td>
</tr>
<tr>
<td>Project written report</td>
<td>Due at 11:59 pm Apr 30</td>
</tr>
<tr>
<td>Project oral report</td>
<td>On Apr 28 (Tue) Lecture and Lab period</td>
</tr>
</tbody>
</table>

The laboratories are available for working on experiments except between the hours of midnight and 7 AM. Please note, though, that **attendance during your regular scheduled laboratory period is required** unless you have made specific other arrangements with your lab instructor.

For the first Lab (Lab1) all students will do the Gaussian Laser Beams experiment. You are to submit a proposal for a sequence of additional experiments that you wish to complete. We do this so that we
can schedule all of the requests to avoid conflicts with equipment usage. The proposal is further described below.

**Scheduled lecture time is Tuesday and Thursday 9 – 9:50 am.** The first lecture period will be an organizational meeting that will include a brief description of the available experiments and the facilities. Experimental write-ups that note any special prerequisites are available on the web site. The remainder of the lecture periods will be used to cover a variety of topics including experimental methods, materials, and techniques. These periods may also be used for organizational purposes, reports, and meetings with students. Attendance is required.

**TEXTBOOK**

The following *optional* texts are available in the lab:

*Building Scientific Apparatus: A practical guide to design and construction*, John H. Moore, Christopher C. Davis and Michael A. Coplan, Perseus Books, Cambridge, MA, 3rd edition, 2003. This text is a valuable resource for experimentalists. Although there are no planned specific assignments from the book, its utility will vastly outlive the semester.

*Experiments in Modern Physics, A. Melissinos and J. Napolitano, Academic Press, 2nd ed., 2003.* (The 1st edition from 1966 is dated in some parts but still very useful.) Once again, there will be no assignments but this book will be useful this semester as well as in your future endeavors. The lab has a few copies of the first edition.

*The Art of Experimental Physics, D. W. Preston and E. R. Dietz, John Wiley & Sons, 1991.* This is extremely useful for the basic skills in experimental physics. The lab has one copy and one copy is reserved in library (24 hour period).

**CONDUCT**

Everything you do in the context of this lab, from writing lab reports, to taking care of your equipment, to giving presentations, is expected to be at a professional level. Please take responsibility for your equipment, take responsibility for your own safety and for the safety of others.

For many of the assignments you will work with one lab partner. Please treat your lab partner with the same degree of courtesy and respect that you would want to be treated with yourself.

Note that while you will often work on the labs with a partner. The notebooks, prelab assignments, activities, and written reports should be *your own work.* If you work on the oral presentation together, submitting identical presentations along with your own lab notebook scan. For final project proposal draft, proposal, project report and presentations, one submission per team should be fine.

**PROPOSALS**

By 4:59 PM Tuesday March 10 you should submit a proposals draft, which must include the partner’s name and a list of possible final projects (maximum 3 and must include one optics lab and one modern physics lab) and their brief description (e.g. motivations, required equipment and accessibility etc.). Feedback on this draft will be returned by Oct 24th to address the feasibility and equipment conflicts.

By 11:59 pm Thursday March 19, you should submit a written proposal project written proposal. It must include (1) the final goals, (2) anticipated obstacles, (3) required equipment, skills and
resources and (4) weekly work schedule for a sequence of four experiments plus two alternate experiments. The instructors will approve proposals, taking care to resolve equipment conflicts. Students should work in pairs throughout the term. When turning in your proposals please indicate the name of your partner for each experiment. Your proposal must include at least one optics lab and one modern physics lab.

For graduate students in PHYS5430, the list can include the standard electronics lab experiments, each of which are one week labs. The 5430 students are also expected to do all “optional” parts in the 4430 labs and to go beyond the material presented in the experiment instructions on some experiments. The 5430 students who have taken 4430 cannot repeat experiments they have done previously.

PROJECTS

Several weeks at the end of the term will be set aside for projects. Projects should be selected in consultation with your instructor during the middle of the semester. They can be anything that offers you a chance to demonstrate independence and creativity. A wide variety of possible experiments or construction projects are acceptable as long as it is something that is not part of a standard experiment presented in one of the write-ups.

GRADING

The grading will be based on pre-labs, lab notebooks, lab reports and oral presentations, and class participation. The table below summarizes the grading scheme. All work is submitted into the CANVAS under ASSIGNMENT.

<table>
<thead>
<tr>
<th>For each standard two-week guided lab:</th>
<th>Semester Total Points</th>
</tr>
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<tbody>
<tr>
<td>- Pre-labs (5 points per lab)</td>
<td>20</td>
</tr>
<tr>
<td>- Lab notebooks (10 points per lab)</td>
<td>50</td>
</tr>
<tr>
<td>- Oral presentation or written lab report (15 points per lab)</td>
<td>75</td>
</tr>
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<table>
<thead>
<tr>
<th>Class participation during semester</th>
<th>Semester Total Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>- 6 activities (5 points each)</td>
<td>30</td>
</tr>
<tr>
<td>- Attendance (1 points per class) + Peer Feedback during oral presentations (1-5 points)</td>
<td>~25 + ~25pt</td>
</tr>
<tr>
<td>- Survey (5 points)</td>
<td>5</td>
</tr>
<tr>
<td>- Lab Attendance (10 pts per Lab and 1pts for 10 min)</td>
<td>150</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Final Project</th>
<th>Semester Total Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Proposals Draft</td>
<td>10</td>
</tr>
<tr>
<td>- Proposal</td>
<td>20</td>
</tr>
<tr>
<td>- Updates (3 Tuesday reports, 5 points each)</td>
<td>15</td>
</tr>
<tr>
<td>- Lab notebook</td>
<td>40</td>
</tr>
<tr>
<td>- Final written report</td>
<td>40</td>
</tr>
<tr>
<td>- Final oral presentation</td>
<td>40</td>
</tr>
<tr>
<td>Total</td>
<td>~ 545</td>
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What is expected for pre-labs, lab notebooks, lab reports, and oral presentations is available on the website (see Guidelines) and will be discussed in class.

Submit your **Oral presentation** and the **written lab report** to Canvas.
Late Assignments will not be accepted. Canvas is set to reject submissions if they are late unless there is a grace period (usually one day). In this case “Available until” date in Canvas is after the due date. The grace period is to allow for technical problems and minor illness, so do not wait until after the due date to submit. Contact your lab instructor as soon as possible in cases of major illness or other serious problems that would prevent you from turning in your assignments on time or showing up to class.

Attendance is required so if you miss a scheduled lab period without being excused by your instructor, you will automatically lose points. If you convince your instructor that you had a sufficiently good reason for missing class (always much easier if you contact the instructor to discuss it before you miss the class) you will be able to make up the class. In addition to the assigned three-hour lab period, it is expected that additional time (usually at least an additional 3 hours/week) in the lab will be needed to complete the experiments plus additional time outside the lab to prepare for the lab, analyze the data, and produce reports. The instructions for each experiment as well as other reference material should be read before each scheduled lab period. Instructions for each experiment are available on the course website.

LAB BOOK
You will be given a lab book with numbered quadrille ruled pages for use in this course. You must keep this lab notebook, which will be used to record your data and all relevant information, including calculations and answers to all questions asked in the guide. Each lab book record must include the original data as recorded in the lab. While your entries must be legible, do not be overly concerned about neatness in the original recording of data; it is more important to record the data directly in the lab book as you do the experiment. It is okay to make mistakes, just make corrections obvious, and strike through sections that should be ignored. Your lab book should be sufficiently complete so that one could reconstruct the experiment at some later date from the information in the lab book without recourse to memory. Upon completion of a lab, you should submit to CANVAS a scan of all relevant lab notebook pages at the same time your presentation or lab report is submitted.

The main office scanner or 5th floor Xerox machine can quickly scan your notebook into a single PDF document and email it directly to you. This is the most efficient way to scan your notebook. If you use Mathematica as a lab notebook, you are still required to print out the notebook pages and tape them in your lab notebook.

LABORATORY
The Laboratory is organized into two major sections: Optics and Modern Physics. The laboratory equipment, electronic and optical components, and tools are organized and labeled. The optics rooms and the electronics lab are equipped with kits of components for the standard experiments. There is a single location in the lab for other components or equipment, except for standard tools, of which there are two sets, one in electronics and one in optics. Please tour the lab and familiarize yourself with the location of these items.

The lab is to be maintained in the condition in which it begins the semester. Of course, while equipment, tools and components can be collected and kept during the course of an experiment, they are to be returned to their homes when the experiment is finished.

EXPERIMENTS

Optics
Gaussian Beams
Diffraction and Fourier Optics
Michelson Interferometer
Hydrogen and Mercury Spectroscopy
Holography
Polarization of Light
Laser Spectroscopy
Laser trapping and cooling

**Modern Physics**

Absolute Measurement of the Faraday
Gamma ray spectroscopy
Pulsed nuclear magnetic resonance
NMR spectroscopy
Lifetime of muons generated by cosmic rays
Soliton propagation
Acoustic reflectometer
X-ray Fluorescence
Raman scattering* (In the lab of Dmitry Reznik)

**CU POLICIES**

**Accommodation for Disabilities**

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the Disability Services website: [www.colorado.edu/disabilityservices/students](http://www.colorado.edu/disabilityservices/students). Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance. If you have a temporary medical condition or injury, see [www.colorado.edu/disabilityservices/students/temporary-medical-conditions](http://www.colorado.edu/disabilityservices/students/temporary-medical-conditions) and discuss your needs with your professor.

**Religious Holidays**

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. Please alert a faculty member about any conflicts you foresee between a religious observance and this class so that an accommodation can be worked out. See the campus policy for full details: [www.colorado.edu/policies/observance-religious-holidays-and-absences-classes-endor-exams](http://www.colorado.edu/policies/observance-religious-holidays-and-absences-classes-endor-exams).

**Classroom Behavior**

Students and faculty each have responsibility for maintaining an appropriate learning environment. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. Class rosters are provided to the instructor with the student’s legal name. I will gladly honor your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the
semester so that I may make appropriate changes to my records. For more information, see the policies on classroom behavior at

www.colorado.edu/policies/student-classroom-and-course-related-behavior and the student code of conduct: www.colorado.edu/osccr/.

Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation

The University of Colorado Boulder (CU Boulder) is committed to maintaining a positive learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct, discrimination, harassment or related retaliation against or by any employee or student. CU’s Sexual Misconduct Policy prohibits sexual assault, sexual exploitation, sexual harassment, intimate partner abuse (dating or domestic violence), stalking or related retaliation. CU Boulder’s Discrimination and Harassment Policy prohibits discrimination, harassment or related retaliation based on race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. Individuals who believe they have been subject to misconduct under either policy should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127. Information about the OIEC, the above referenced policies, and the campus resources available to assist individuals regarding sexual misconduct, discrimination, harassment or related retaliation can be found at the OIEC website: www.colorado.edu/institutionalequity/.

Honor Code

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the academic integrity policy: www.colorado.edu/policies/academic-integrity-policy. Violations of the policy may include: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, resubmission, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code Council (honor@colorado.edu; 303-735-2273). Students who are found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code Council as well as academic sanctions from the faculty member. Additional information regarding the academic integrity policy can be found at www.colorado.edu/honorcode/.